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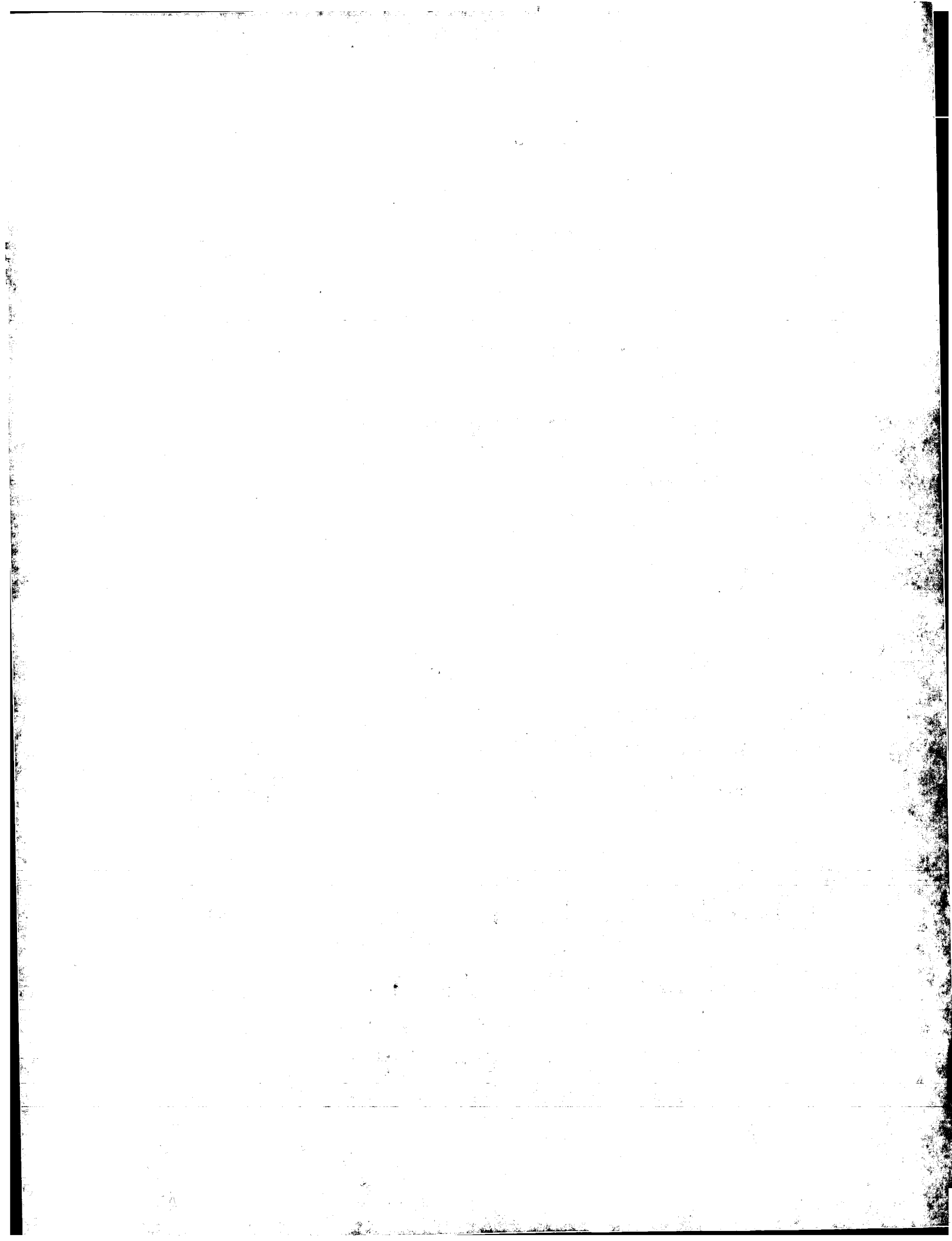
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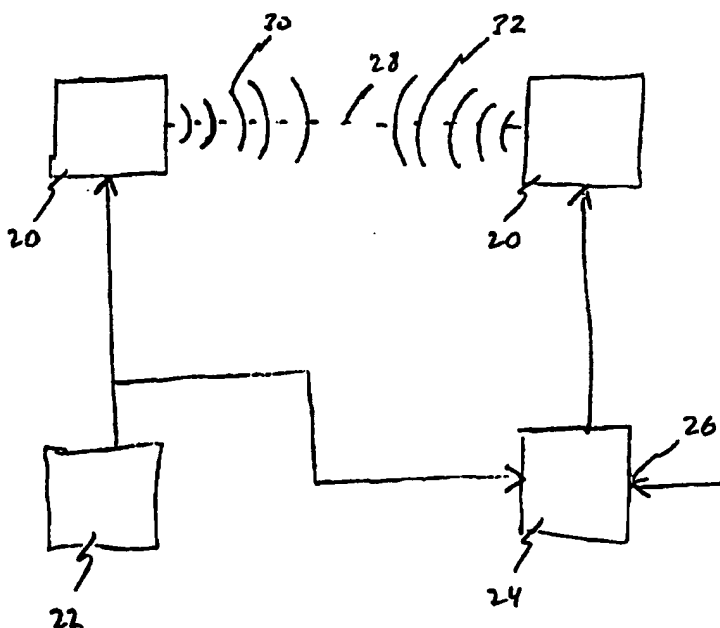
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>H04B 3/00</b>	<b>A1</b>	(11) International Publication Number: <b>WO 98/02977</b> (43) International Publication Date: 22 January 1998 (22.01.98)
(21) International Application Number: PCT/US97/12393 (22) International Filing Date: 16 July 1997 (16.07.97) (30) Priority Data: 08/683,504                  17 July 1996 (17.07.96)                  US (71) Applicant: AMERICAN TECHNOLOGY CORPORATION [US/US]; 12725 Stowe Drive, Poway, CA 92064 (US). (72) Inventor: NORRIS, Elwood, G.; 13824 San Sebastian Way, Poway, CA 92064 (US). (74) Agents: NORTH, Vaughn, W. et al.; Thorpe, North & Western, L.L.P., 9035 South 700 East, Sandy, UT 84070 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  Published With international search report.

(54) Title: ACOUSTIC MIXING DEVICE AND METHOD

## (57) Abstract

The present invention is the emission of new sonic or subsonic compression waves from a region of interference of at least two ultrasonic wave trains (30, 32). In one embodiment, two ultrasonic emitters (20) are oriented so as to cause interference between emitted ultrasonic wave trains (30, 32). When the difference in frequency between the two ultrasonic wave trains (30, 32) is in the sonic or subsonic frequency range, a new sonic or subsonic wave train of that frequency is emitted from within the region of interference. The preferred embodiment is a system comprised of a single ultrasonic radiating element (20) emitting multiple waves. A key aspect of the invention is to superimpose intelligence onto one or both of the ultrasonic carrier waves. This intelligence is then extractable as a new sonic or subsonic frequency wave train which is a by-product of the interference of at least two ultrasonic frequency carrier waves.



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**ACOUSTIC MIXING DEVICE AND METHOD****BACKGROUND OF THE INVENTION****1. Field of the Invention**

5        This invention pertains to compression wave generation. Specifically, the present invention relates to a device and method for indirectly generating a sonic or subsonic compression wave without the use of a direct radiating element at the source of the compression wave  
10       generation.

**2. State of the art**

      Sound waves in general are wave-like movements of air or water molecules. Because these media are elastic  
15       and generally homogeneous, naturally occurring sound travels in all directions radially from the source of generation. A voice, instrument or impact, for example, will radiate omni-directionally in a unitary, integrated form, carrying multiple frequencies, overtones, and a  
20       full range of dynamics that collectively contribute to an instantaneous sound perception at the ear. This perception of naturally occurring sound at a healthy ear is deemed to be "pure" when it corresponds to the same acoustic content that existed at the point of origin.

25       Because sound is a transient, temporary state of motion within a media, it is not self-sustaining. Indeed, the first and second laws of thermodynamics require that the sound eventually dissipate its motion into heat or other forms of energy. Therefore, if  
30       storage or preservation of the sound is desired, it is necessary to transmute such motion into a fixed form of recording. This fixed form can then be recovered later by conversion of the fixed form back into sound waves.

      In the earliest experiences of recording,  
35       mechanical devices were moved by impact of the sound waves to inscribe or etch a corresponding groove into a plate. By running a needle or other tracking device over a set of grooves, crude reproduction of the

original sound waves was accomplished. More sophisticated technologies have developed which enable capture of sound waves in other fixed forms such as magnetic, electronic, and optical media. Nevertheless, the same principle of sound reproduction has been applied to recover this stored information, whether the response is generated by a mechanical mechanism or by digitally controlled laser reading devices. Specifically, stored signal is converted back to sound waves by recreating movement of an object, which then sets the surrounding air into motion corresponding to sound reproduction.

A primary goal of modern acoustic science is to reproduce pure sound, based on conversion of the electronic, magnetic, mechanical or optical record into compression waves which can be detected at the ear. The ideal system would play all original sound back through a resonating device comparable to that which produced the sound in the beginning. In other words, the violin sounds would be played back through a violin, regenerating the overtones and a myriad of other dynamic influences that represent that instrument. Similarly, a piccolo would be played back through a device that generates the high frequencies, resonance aspects and overtones associated with this type of instrument. In short, one cannot expect a viola to sound like a viola in "pure" form if sound reproduction is actuated by a mechanical wave generating device that does not embody unique characteristics of that instrument or voice. Accordingly, it would seem that the only practical way to reproduce the original "pure" quality of sound would be to isolate each instrument or source, record its sound output, and then reproduce the output into the same instrument or acoustic resonator. It is apparent that such a solution is totally impractical.

In the real world, the challenge of reproducing sound has been allocated to the speaker. The operation

of a loudspeaker is relatively simple to understand when the interaction of the components is explained. A speaker is a transducer which receives energy in one form (electrical signals representative of sound) and translates the energy to another form (mechanical vibration). In a dynamic loudspeaker, an electrical current that is proportional to the strength and frequency of the signal to be broadcast is sent through a coil attached to a rigid membrane or cone. The coil moves inside a permanent magnet, and the magnetic field exerts a force on the coil that is proportional to the electrical current. The oscillating movement of the coil and the attached membrane sets up sound waves in the surrounding air. In brief, reproduction of sound has heretofore required mechanical movement of a diaphragm or plate. To expect a single diaphragm or plate to accurately supply both the shrill sound of the piccolo and the deep resonance of the base drum would indeed be unreasonable.

It is important to note, however, that when the listener at a live performance of a symphony hears this broad range of sound, he receives it in an integrated manner as a "unified" combination of sound waves, having a myriad of frequencies and amplitudes. This complex array is responsively promulgated through the air from its originating source to an ear that is incredibly able to transfer the full experience to the brain. Indeed, the full range of audible signal (20 to 20,000 Hz) is processed as a unified experience, and includes effects of subsonic base vibrations, as well as other frequencies which impact the remaining senses.

It is also important to note that this same "pure" sound that arrives at the ear, can be detected by a microphone and consequently recorded into a fixed media such as a cassette tape or compact disc. Although the microphone diaphragm may not have the sensitivity of a human ear, modern technology has been quite successful

in effectively capturing the full range of sound experience within the recorded signal. For example, it is unnecessary to provide separate microphones for recording both low and high range frequencies. Instead, 5 like the ear drum, the microphone captures a unified sound waveform and registers this as a composite signal that can then be recorded onto an appropriate media.

It is therefore clear that the microphone is not the primary limitation to effective reproduction of 10 "pure" sound. Rather, the challenge of accurate sound reproduction arises with the attempt to transform the microphone output to compression waveforms through a mechanical speaker. Accordingly, the focus of effort for achieving a unified sound system has been to develop 15 a complex speaker array which is able to respond to high, medium and low range frequencies, combining appropriate resonance chambers and sound coupling devices, to result in a close simulation of the original sound experience.

20 This quest for improved sound reproduction has included studies of problems dealing with (a) compensating for the mass of the speaker diaphragm, (b) the resistance of air within an enclosed speaker, (c) the resonant chamber configuration of the speaker, (d) 25 the directional differences between high and low frequencies, (e) the speed variation of low versus high frequency compression waves, (f) the difficulty of coupling speaker elements to surrounding air, and (g) the loss of harmonics and secondary tones. Again, these 30 aspects represent just a few of the problems associated with reconstructing the sound wave by means of a physical speaker.

As an example of just one of these issues, overcoming the mass of a speaker driver has remained a 35 challenging problem. Obviously, the purpose of the speaker driver and diaphragm is to produce a series of compression waves by reciprocating back and forth to



form a compression wave. The initial design challenge is to compensate for resistance against movement in speaker response due to inertia within the speaker mass. Once the speaker driver is set in motion, however, the mass will seek to stay in motion, causing the driver to overshoot, requiring further compensation for delayed response to reverse its direction of travel. This conflict of mass and inertia recurs thousands of times each second as the speaker endeavors to generate the complex waveform of the original sound embodied in the electrical signal received.

In order to meet the difficulty of compensating for mass, as well as numerous other physical problems, speaker development has focused mainly on improving materials and components as opposed to developing a different concept of sound generation. Diaphragm improvements, cone construction materials, techniques and design, suspensions, motor units, magnets, enclosures and other factors have been modified and improved. Nevertheless, the basic use of a reciprocating mass remains unchanged, despite the inefficiency of less than 5 percent of the electrical power being converted to acoustic response.

Electrostatic loudspeakers represent a different methodology. Unlike the electrodynamic loudspeaker with its cone shaped diaphragm, the electrostatic loudspeaker uses a thin electrically conducting membrane. Surrounding the plate are one or more fixed grids. When a signal voltage is applied to the elements, the electrostatic force produced causes the diaphragm to vibrate. This low-mass diaphragm is particularly useful as a high-frequency radiating element, and its operation can be extended to relatively low frequencies by the use of a sufficiently large radiating area.

Although electrostatic speakers offer some advantages, they are huge, inefficient and suffer from the lack of point source radiated sound. For example,

sound detection is accomplished by a microphone at a localized or point source. To convert the detected sound to a non-point source such as a large electrostatic diaphragm may create an unnatural sound reproduction. Specifically, a radiating element 5 feet in height is limited in its ability to simulate the delicate character of a piccolo or violin.

Another issue in loudspeaker design is that the optimum mass and dimensions for low frequency radiating elements differ radically from those for high frequency. This problem is typically addressed by providing both woofer and tweeter radiating elements for each channel of a loudspeaker system. The implications of this design are highly undesirable. The phase shift introduced because of the differences in time delay for high frequency signals traveling the shorter distance of the cone of a tweeter to a listener, versus (ii) the substantially longer path for low frequency signals from the horn or woofer speaker to a listener's ear can be in the range of thousands of percent in phase differential.

This discussion of speaker technology is recited for a single purpose--to emphasize the difficulty of changing a fixed form of sound to a compression wave which is capable of reproducing sound in its original form. Nevertheless, the prior art has been virtually dominated for sixty years by the concept that mechanical systems, such as speakers, are required to reproduce audible sound. Clearly, it would be very desirable to provide a means of sound reproduction which adopts a different approach, avoiding the many difficulties represented by the choice of moving a diaphragm or speaker in order to generate sound.

#### OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and apparatus for indirectly emitting sonic and subsonic compression waves from a region of air without

using a direct radiating element to emit the compression waves.

It is another object to indirectly generate at least one sonic or subsonic compression wave by using a  
5 by-product of interference between at least two ultrasonic signals having different frequencies equal to the at least one sonic or subsonic compression wave.

It is still another object to cause at least two ultrasonic compression waves to interact to thereby  
10 extract intelligence from the interfering compression waves.

It is yet another object to indirectly generate sonic or subsonic compression waves by combining them with an ultrasonic carrier wave using amplitude  
15 modulation, emitting the combined signal from an ultrasonic transducer, causing interference between the carrier wave and another ultrasonic compression wave, and thereby create the sonic or subsonic compression waves.

It is still another object to affect a physical state of a living being utilizing an indirectly radiated compression wave.  
20

It is still yet another object to generate a compression wave which is perceptible to human senses  
25 using at least two imperceptible compression waves, but without directly propagating the compression wave.

Yet another object of the invention is to generate a sonic or subsonic compression wave without having to overcome the mass and associated inertial limitations of  
30 a conventional direct radiating element.

Still another object of the invention is to generate a sonic or subsonic compression wave without introducing distortions or undesired harmonics otherwise inherent to a conventional direct radiating element.

35 Another object is to indirectly generate and enhance a sonic or subsonic compression wave from within

a resonant cavity by emitting at least two ultrasonic compression waves into the resonant cavity.

Yet another object is to omni-directionally generate a high frequency compression wave, thereby  
5 avoiding the highly focused and directional nature of high frequency signal emissions typical of a conventional loudspeaker.

Still yet another object is to generate a sonic or subsonic compression wave in a localized area without  
10 coupling to an associated environment or enclosure which would otherwise cause undesirable broadcasting of the sonic or subsonic compression wave.

Yet another object is to generate a sonic or subsonic compression wave wherein characteristics of the  
15 sonic or subsonic compression wave are not limited by the characteristics of a direct radiating element.

Another object of the invention is to emulate a sound wave detection process typical of a point-source detection device such as a microphone, but without  
20 providing a physical detection device at a detection location.

Another object is to control the volume of a sonic or subsonic compression wave by manipulating the degree of interaction of the at least two ultrasonic  
25 compression waves.

Still another object is to emit a sonic or subsonic compression wave from a region of air as a by-product of an ultrasonic compression wave being emitted from a single ultrasonic transducer into the region.

30 The present invention is embodied in at least two different systems, each using a different method for indirectly generating sonic or subsonic sound waves. In the first embodiment, a sonic or subsonic compression wave is emitted from a region of interference of at  
35 least two ultrasonic compression waves. The principle of operation is based on generating a by-product of interference of the at least two ultrasonic compression

waves. The interference generates a by-product which is the difference in frequency between the compression waves.

A system which demonstrates this by-product concept  
5 is comprised of two ultrasonic emitters which are oriented so as to cause interference between emitted ultrasonic compression waves. When the difference in frequency between the two ultrasonic compression waves is in the sonic or subsonic range, a sonic or subsonic  
10 compression wave equal to this difference is generated from within a region of interference.

The different embodiment of the system provides the advantage of only being comprised of a single ultrasonic direct radiating element. The advantage is not only the  
15 decreased amount of hardware, but the perfect alignment of the two interfering ultrasonic compression waves because they are emitted from the same radiating element. In effect, the sonic or subsonic wave train appears to be generated directly from the ultrasonic  
20 emitter. If it were not for the inescapable conclusion that the ultrasonic emitter cannot generate sonic or subsonic frequencies, plus the audible evidence that the sound is not emanating directly from the emitter, one might be deceived.

25 The importance of the first embodiment is that it teaches the concept of generating a sonic or subsonic wave train as a result of the interference between two ultrasonic wave trains. In essence, it is easier to see that two ultrasonic wave trains are coming from two  
30 ultrasonic emitters. But the principle of generating a new compression wave from two ultrasonic compression waves prepares the way for understanding how the second embodiment functions.

A key aspect of the invention is the discovery that  
35 by superimposing sonic or subsonic intelligence onto an ultrasonic carrier wave, this intelligence can be retrieved as a new sonic or subsonic wave train.

Whether the ultrasonic wave trains are generated from two emitters or from a single emitter, the effect is the same.

Another aspect of the invention indirect generation  
5 of compression waves without having to overcome the problems inherent to mass and the associated limitations of inertia of a conventional direct radiating element. The present invention eliminates a direct radiating element as the source of a compression wave so that the  
10 desired sound is generated directly and distortion free from a region of air.

The present invention has proven to affect a large number what are sometimes perceived as unrelated topics. A list is provided which highlights the aspects which  
15 have already been introduced as well as the aspects yet to be revealed hereafter. These aspects of the invention include 1) indirectly generating a sonic, subsonic or ultrasonic compression wave, 2) superimposing intelligence on an ultrasonic carrier wave  
20 and retrieving the intelligence as the indirectly generated compression wave, 3) causing at least two ultrasonic compression waves to interact in air and using the by-product of the interference, 4) generating the compression wave from a relatively massless  
25 radiating element (air) to avoid the distortion and undesirable harmonics of conventional direct radiating elements, 5) affecting a physical state of a living being by generating subsonic frequencies in close proximity thereto, 6) generating approximately a near  
30 point-source of sound, 7) eliminating distortion in playback or broadcasting of sound, 8) eliminating the "beaming" phenomenon inherent in emission of high frequency compression waves from a direct radiating element, 9) generating a sonic or subsonic compression  
35 wave which is independent of the characteristics of the direct radiating element, 10) detecting sound without using a direct detection device at a detection location,

11) eliminating the phase shift typical of a multi-element loudspeaker system, and 12) generating a compression wave regardless of the characteristics of the radiating element.

5        It should be remembered that all these aspects of the present invention are possible without using a speaker capable of generating the desired sonic or subsonic frequencies. Furthermore, these sonic or subsonic frequencies are generated absolutely free of  
10 distortion and in omni-directional orientation. The surprising result is the recreation of "pure" sound in the same form as when it was originally captured at a microphone or other recording system.

15        These and other objects, features, advantages and alternative aspects of the present invention will become apparent to those skilled in the art from a consideration of the following detailed description taken in combination with the accompanying drawings.

20        **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a block diagram of the components of a loudspeaker assembly of the state of the art.

25        Figure 2 is a block diagram of the components of an indirect compression wave generation system which is built in accordance with the principles of one embodiment of the present invention.

30        Figure 3 is an illustration of the indirect compression wave generation using the apparatus of FIG. 2, including the interference effect which generates the desired sonic or subsonic compression wave.

Figure 4A is a graph showing frequency drift which alters the desired compression wave when two separate frequency generators are used.

35        Figure 4B is a graph showing how frequency drift becomes irrelevant if both compression waves drift together.

Figure 5 is an alternative embodiment of the present invention using two separate frequency generators.

Figure 6 is an alternative configuration of ultrasonic transducers to indirectly generate compression waves.

Figure 7 is another alternative configuration of ultrasonic transducers to indirectly generate compression waves.

Figure 8 is an illustration of the preferred embodiment of the present invention which only requires a single ultrasonic emitter to indirectly generate compression waves.

Figure 9 is an alternative embodiment of FIG. 8.

Figure 10 is an illustration of a resonant cavity with two ultrasonic signals being emitted inside to interact.

Figure 11 is a diagram of new headphones and the human ear as the resonant cavity.

Figure 12 illustrates a system for recording sound without having to provide a physical microphone element at a compression wave sensing location.

Figure 13 is a graph showing how air responds increasingly non-linearly as the amplitude or intensity of sound increases.

Figure 14 is a graph showing when air responds non-linearly to a specific signal of a defined frequency and amplitude.

Figure 15 is an embodiment which teaches reflection of the ultrasonic frequency signals to develop acoustical effects.

#### DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made to the drawings in which the various elements of the present invention will be given numerical designations and in which the



invention will be discussed so as to enable one skilled in the art to make and use the invention.

The present invention is a dramatic departure from the teachings of the present state of the art.

5 The creation of compression waves is generally perceived to be a direct process. A direct process is defined as causing a radiating element 10 to vibrate at a desired frequency as shown in FIG. 1. The system of FIG. 1 is typically used to directly generate  
10 audible and inaudible compression waves, both above and below the range of human hearing. A conventional compression wave generating system is thus comprised of a speaker element 10 which can be any dynamic, electrostatic or other direct radiating element, and a  
15 signal source such as a signal generator or amplifier 12. The signal source 12 supplies an electrical signal representative of a compression wave having a specific frequency or frequencies at which the speaker element 10 will vibrate to produce compression waves  
20 14.

To improve the quality of sound from a sound reproduction system such as in FIG. 1, a person skilled in the art presently looks at ways to improve the physical radiating element such as the loudspeaker  
25 10. The loudspeaker 10 functions as a transducer trying to accurately reproduce sound recorded in an analog or preferably a digital format by converting an electrical signal into compression waves 14. Therefore, until now, generating compression waves has  
30 been a direct process as previously defined. The reproduced sound is generated directly by a physical radiating element which vibrates at the frequency or frequencies of the electrical signal which drive it. This vibration typically drives a loudspeaker cone or  
35 diaphragm which creates the compression waves 14 which the human ear can hear when within the range of 20 to 20,000 cycles per second. For example, the diaphragm

vibrates at 1500 cycles per second to generate an audible tone of 1500 Hz.

Before proceeding further, it will be helpful to define several terms which will be used hereinafter.

5 A "signal source" will interchangeably refer to a "signal generator" or "amplifier" which provide electrical signals representative of compression waves to be emitted from a speaker. The term "speaker" will interchangeably refer to the terms "transducer",  
10 "emitter", "loudspeaker", "diaphragm", "physical radiating element" or "direct radiating element" which convert the electrical signals to a mechanical vibration causing compression waves. The term "compression wave" will interchangeably refer to the  
15 terms "sound wave", "longitudinal wave" and "wave train" which are sonic, subsonic and ultrasonic waves propagating through a transmission medium such as air.

The present invention in a preferred embodiment teaches a method and apparatus for indirectly  
20 generating a compression wave. Indirect generation refers to the absence of a direct radiating element at the source of the compression wave generation. Surprisingly, there is no physical radiating element vibrating at the frequency of the newly generated  
25 compression wave. Instead, air molecules are caused to vibrate at the desired sonic, subsonic or ultrasonic frequency to thereby function as the radiating element and generate the compression wave. The air itself becomes the direct radiating element,  
30 and the air is caused to vibrate indirectly.

Of greatest interest to the present invention are both sonic and subsonic frequencies. This is largely due to the difficulty in directly generating these frequencies without distortion. In contrast, it is  
35 the nature of ultrasonic frequencies that they can be generated with much greater precision and consequently with less distortion because the radiating element is

typically more efficient, smaller and less massive, and is not subject to the same causes of distortion as are conventional speakers that directly generate audio frequencies. Therefore, although it should be  
5 remembered that the invention can generate compression waves at ultrasonic frequencies indirectly, the present focus is on indirect generation of sonic and subsonic compression waves such as those which represent music, voice and all other forms of sound.

10 To generate a compression wave, the present invention 1) makes use of at least two ultrasonic signals, 2) superimposes a desired sonic or subsonic signal onto one or both of the ultrasonic signals, 3) emits the ultrasonic signals from at least one  
15 ultrasonic emitter 4) causes the ultrasonic signals to interfere, and 5) generates a new compression wave from a region of interference of the ultrasonic compression waves.

The advantages of this arrangement are  
20 immediately observable. The ultrasonic component waves do not impact upon the human ear in a perceptible form and are therefore non-distracting. Consequently, only the desired compression wave is perceived by a listener and is capable of recreating  
25 the original waveform for generation of more ideal sound reproduction.

Introduction of the present invention is best understood by reference to FIG. 2. Other more preferred embodiments will be explained hereafter,  
30 based on the principles of this initial discussion.

Indirect compression wave generation is accomplished in a first embodiment as illustrated in FIG. 2. The fundamental elements of the system include at least two ultrasonic acoustical transducers  
35 20, an ultrasonic signal source 22, a means for combining signals 24, and an input 26 to the means for combining signals which provides a signal to be

superimposed upon a carrier signal. The ultrasonic signal source 22 also functions as a means for controlling the frequency of signals being emitted from the at least two ultrasonic acoustical transducers 20. The dotted line 28 indicates that in this first embodiment, the orientation of the transducers 20 are coaxial for purposes to be explained.

The apparatus above is able to function as described because of an unexpected result of applying the beat principle. It is well known that two audible sounds having different frequencies can interfere to generate a beat frequency. The number of beats per second equals the difference of the frequencies of the component (fundamental) waves. The present invention uses this principle to obtain the unexpected result that this beat or by-product can carry extractable intelligence if the fundamental waves are ultrasonic.

The method of superimposing the sonic or subsonic compression wave onto the at least two radiating element system of FIG. 2 specifically involves a frequency difference or sweeping technique. In other words, a first ultrasonic carrier wave 30 might be kept steady at 40 KHz. The second ultrasonic carrier wave 32 can, for example, be swept from 40 KHz up to 41 KHz, and then back down again. The listener hears a wavering tone, where the compression wave correspondingly varies in its range of frequency from 0 Hz up to 1 KHz and then back down to 0 Hz.

The formula which expresses the formation of the compression wave is  $f_{\text{new}} = f_2 - f_1$ . The ultrasonic wave  $f_2$  is the ultrasonic wave which is carrying the intelligence in the form of the superimposed compression wave. The ultrasonic wave  $f_1$  is the base carrier wave which typically will not vary, but can also be varied if desired.

The preferred transmission medium of the present invention is air because it is a highly compressible medium that easily responds with a beat frequency. However, any fluid can function as the transmission medium if desired.

FIG. 3 shows the generally coaxial and interfering ultrasonic compression waves 30, 32. It may be assumed that the transmission medium is air. A region of interference 34 is shown where the two ultrasonic waves 30, 32 interact. The interference in this region results in a compression wave 36 which is not a new wave, but rather exists only under the beat frequency principle. This compression wave 36 radiates generally outward in all directions (omni-directionally) from this region of interference 34.

This surprising result is readily verified by the audible compression wave 36 (if the difference in frequency is sonic) radiating omni-directionally outward from the region 36 of air where interference occurs. It is further noted that the compression wave appears to be enhanced where the superposition is reflected from a surface such as a table, ceiling or wall. This phenomenon may be utilized to bring a perception of multi-dimensionality to sound reproduction.

One of the unexpected aspects of the present invention is that it is using the by-product of interference and manipulating the ultrasonic carrier waves so that the by-product carries intelligence. Typically, compression wave applications try to minimize or eliminate any by-product which might be formed as a consequence of their use. The present invention distinguishes itself from the prior art by doing just the opposite--it maximizes the by-product to produce a wave component.

The intelligence being referred to above is any compression wave which carries information which may

be extracted therefrom. For example, the compression wave might be in the audible range of human hearing, and could be a radio transmission such as might be received by a receiver in a stereo sound system or in  
5 a car. Alternatively, the compression wave could be subsonic.

One aspect to consider is that the invention performs more efficiently when the ultrasonic carrier waves are higher in frequency. This is understandable  
10 when realizing the mechanism by which the compression wave is being generated. Molecules of air are being caused to vibrate at the frequency of the compression wave, which is a direct result of movement of the air by the carrier waves. The ultrasonic carrier waves  
15 more efficiently couple to the air molecules at higher ultrasonic frequencies than at lower ultrasonic frequencies, thereby obtaining the advantage of enhanced efficiency with higher frequency.

There are also several factors which affect the  
20 characteristics of the compression wave. Volume or amplitude of the compression wave is controlled by several factors. One factor is the energy contained within the ultrasonic carrier waves. Obviously, the energy for the compression waves must necessarily come  
25 from the ultrasonic carrier waves. An ultrasonic carrier wave with a higher velocity contains more energy than an ultrasonic carrier wave with a lower velocity.

Amplitude is another factor which affects the  
30 volume of the compression wave. Greater amplitude of the ultrasonic compression waves results in greater amplitude of the compression wave.

Transducer orientation also greatly affects the compression wave. It has been stated that the  
35 ultrasonic carrier waves must interact to generate the compression wave. However, there are many degrees of interaction. The orientation shown in FIG. 2 is of

two transducers 20 which are generally maximizing interference by turning emitting surfaces directly towards each other and then orienting the transducers so as to be coaxial with respect to the emitted  
5 ultrasonic carrier waves. However, the orientation of ultrasonic transducers 20 in FIGs. 6 and 7 show that orientation might vary greatly. For example, FIG. 6 shows two ultrasonic acoustical transducers 20 oriented substantially parallel to each other, but  
10 creating ultrasonic signals (and emphasized by paths 70) which eventually cross at some distance from the transducers 20.

Another orientation of the transducers 20 is shown in FIG. 7 which varies from the orientation  
15 shown in FIG. 6 in that axes of the ultrasonic compression waves 30, 32 following paths 70 do not actually cross, but are sufficiently close such that the fringe of the waves 30, 32 sufficiently interfere to enable generation of the compression wave.

20 Regarding the elements of the present invention in FIG. 2, it should also be observed that there is an advantage to using one signal source 22 to generate the ultrasonic compression waves 30, 32 to be emitted by the ultrasonic transducers 20. The advantage of  
25 this arrangement is that signal differences that might otherwise occur due to variations in temperature or performance of two separate signal sources would likely lead to drift between the frequency values of the waves 30, 32. Furthermore, because it is the  
30 difference in frequency between the two ultrasonic signals 30, 32 being generated which is ultimately the frequency of the generated compression wave 36 which is of interest, it is important to minimize unintentional frequency variations. To accomplish  
35 this, a single ultrasonic signal source 22 is generating both output signals 30, 32 so that they

will drift together if at all, and thus make it easier to control the compression wave.

For example, FIG. 4A is a graph showing ultrasonic carrier waves 30 and 32. Assume that the  
5 desired compression wave is a tone of 1 KHz, represented by the designation 50. The difference in frequency between ultrasonic compression waves 30 and 32 will generate this tone. However, wave 32 is shown to be drifting upward in frequency by an amount  
10 designated as 51. Consequently, the compression wave will have a tone designated by the difference in frequency designated as 52 instead of 51.

In contrast, FIG. 4B illustrates the effect of using a single ultrasonic signal source 22 (FIG. 1).  
15 The ultrasonic carrier waves 30, 32 are shown to drift together, resulting in an overall net change in frequency of zero because they are separated by a distance 50 of 1 KHz before, during and after drifting.

20 A frequency control device 24 was also previously mentioned as being necessary for concurrently operating the ultrasonic acoustical transducers 20. The frequency control device 24 can perform the function of altering one or both of the ultrasonic  
25 signals 30, 32 being generated by the ultrasonic signal source 22. The frequency control device 24 superimposes the first ultrasonic compression wave 30 with a desired electrical signal representing the desired compression wave frequency or frequencies 36.  
30 The combination is defined as the sum of the frequencies of the first ultrasonic compression wave 30 and the desired compression wave frequency or frequencies and is emitted as the second ultrasonic signal 32.

35 The final elements of the system shown in FIG. 2 are the two ultrasonic transducers 20. These ultrasonic transducers 20 emit compression waves at



ultrasonic frequencies using devices such as piezoelectric transducers. There is one basic observation which makes the advantage of using ultrasonic acoustical transducers 20 more significant.

5 If the only desired audible sound is the difference in frequency between the first and the second ultrasonic signals 30, 32, then emitting anything but an inaudible signal would defeat the purpose of the invention. The present invention advantageously emits

10 ultrasonic signals which result in only one audible compression wave being generated as a by-product of the interference between the ultrasonic compression waves.

FIG. 5 illustrates the observation that there are

15 other ways to deliver electrical signals representing the ultrasonic compression waves 30, 32 to the ultrasonic transducers 20 instead of using a single ultrasonic signal source 22. For example, two separate ultrasonic sources 40, 42 might be provided

20 as shown in FIG. 5, although the risk of frequency drift becomes more relevant. This embodiment might also require some type of synchronization between the two ultrasonic signal sources 40, 42. For example, a synchronizing controller 44 might coordinate

25 transmission of the two ultrasonic signals 30, 32.

The embodiment of FIG. 2 teaches the principle that interfering waves 30, 32 generate a compression wave which is carrying intelligence as the difference in frequency between them. If the interfering waves

30 30, 32 are ultrasonic and the frequency difference is within the sonic or subsonic frequency range, a compression wave is generated which has a frequency equal to the difference in frequency of the interfering waves. This embodiment is shown as FIG.

35 8, and is structurally different from the preferred embodiment because it is possible to generate the

compression wave as a result of interfering ultrasonic carrier waves, but only using one radiating element.

The concept of only using a single radiating element may initially appear inconsistent with the teachings of the present invention when compared with the formula for the compression wave,  $f_{\text{new}} = f_2 - f_1$ , which clearly requires two carrier waves. However, all the elements of the invention are still present. The first ultrasonic carrier wave  $f_1$  may be assumed to be the ultrasonic compression wave being generated by the signal source 22. The second ultrasonic compression wave is the combination of the first ultrasonic compression wave and a sonic or subsonic which is wave superimposed upon it by amplitude modulation. Subtracting the first ultrasonic wave from the second amplitude modulated ultrasonic wave results in the indirect generation of the compression wave. Although seemingly being emitted from the single ultrasonic emitter 20, the sonic or subsonic compression wave is still the by-product of the interference of ultrasonic compression waves.

The elements of the system shown in FIG. 8 include the ultrasonic transducer 20 generating the ultrasonic carrier wave 60 with the desired intelligence amplitude modulated thereon. The resulting compression wave 36 is shown being generated from the carrier wave 60. Supplying an ultrasonic signal to the apparatus is an ultrasonic signal source 22. The ultrasonic carrier wave generated therefrom is sent to an amplitude modulator 62 which amplitude modulates a sonic or subsonic signal 64 onto the ultrasonic compression wave 60.

One other aspect of this preferred embodiment should also be emphasized. The first embodiment superimposes a desired sonic or subsonic signal onto a carrier wave which is expressed as a sweeping of frequencies. In contrast, a single emitter of the

preferred embodiment functions to generate the compression wave when the desired sonic or subsonic signal (compression wave) is amplitude modulated onto the ultrasonic carrier wave. The later, preferred  
5 embodiment may give the mistaken impression that an ultrasonic transducer is somehow miraculously generating bass frequencies. This misconception arises, however, because the interference of the two ultrasonic compression waves is occurring generally  
10 directly in front of the ultrasonic transducer 20. And yet, it is not the transducer 20 which is directly generating the compression wave, but rather the air directly in front of the transducer which is indirectly caused to vibrate at the frequencies of the  
15 compression wave.

FIG. 9 is provided to show more intuitively that two separate and distinct ultrasonic compression waves (carrier waves) are being generated from separate signal sources 22, and then remitted from the  
20 transducer 20 to generate the desired compression wave.

The implications of producing sound in midair in accordance with the present invention represents a profound step forward in the sound reproduction  
25 technology. Although many applications may not be immediately apparent from the present disclosure, the following examples will illustrate the broad versatility and advantage of this concept.

The present invention teaches a method for  
30 indirectly generating at least one sonic or subsonic frequency from the transmission of at least two ultrasonic frequencies of different value which interact. The ultrasonic frequencies can be generated from a single emitter or from at least two emitters,  
35 but the method of superimposing intelligence on the carrier waves varies depending upon the number of emitters being used. If two emitter are being used,

then the desired frequency is varied by sweeping through a desired frequency range. However, if one emitter is used, the method comprises amplitude modulating a desired sonic or subsonic signal onto the  
5 ultrasonic compression waves.

The present invention also generates sound from a nearly massless radiating element which is at all times in motion and which only shifts a small percentage of its fundamental frequency in order to  
10 co-generate frequencies which span the entire audio spectrum. In the region of interference and consequently in compression wave generation, there is no physical radiating element other than a region of air itself in the preferred embodiment. The great  
15 significance of this aspect is readily grasped by those who have endeavored unsuccessfully to create a radiating element free of distortion effects caused by the radiating element itself. For example, harmonics on a loudspeaker cone, cone overshoot and cone  
20 undershoot caused by inertia, and the imperfect surface of the cone are all factors which contribute to signal distortion attributable to a direct radiating element.

A direct physical radiating element has other  
25 undesirable qualities as well. Despite certain manufacturers claims to the contrary, the frequency response of a direct radiating element is not truly flat, but instead is a function of the specific band of frequencies which it is inherently best suited for.  
30 To achieve a flat response, manufacturers have gone so far as to construct loudspeaker cone material from Kevlar in an attempt to try and dampen undesirable harmonics and improve fidelity. The present  
invention, on the other hand, does not require such  
35 extreme measures because there is no physical direct radiating element. The radiating elements which are essential to the system are ultrasonic transducers

which are inherently less susceptible to the distortion effects found in lower frequency radiating elements.

5 This aspect of indirect sonic or subsonic compression wave generation of the present invention provides a giant step toward achieving truly indirect sound reproduction with original sound quality. While the state of the art has advanced the ability to convert an analog signal to a digital recording, and  
10 to even process the signal digitally, the quality of sound reproduction has always been limited by the mechanical speaker element. This is no longer the case because the present invention achieves truly distortion free sound which is not hindered by the  
15 mass and associated inertial limitations of a radiating element.

In a related aspect of the invention, Another aspect is that affecting living beings gives rise to the possibility of unobtrusively generating crowd-  
20 controlling subsonic sound waves. Very low frequencies, such as those around 12 Hz, have been shown to nauseate or disorient human beings and other animals. This principle may have applications in crowd control.

25 Other aspects of the invention include the advantages of providing approximately a near point-source of sound. The present invention substantially eliminates phase distortion created by multi-speaker systems designed to more efficiently reproduce the  
30 various frequencies of sound. The advantage of this aspect is the ability to accurately reproduce the effect of point-source sound with a highly directional sense of orientation for the listener. This is the ultimate goal of sound reproduction which until now  
35 has never been fully realized.

Another aspect of the present invention is the orientation of the ultrasonic transducers 20. As a

practical matter, the present invention functions best when there is maximum interference of the ultrasonic carrier waves by emitting the carrier waves coaxially. This orientation is inherent in a single emitter  
5 system. However, this orientation is best achieved in a two emitter system by orienting them to be diametrically opposite so as to present two emitting faces which are generally coaxial. This is essentially the orientation of the ultrasonic  
10 acoustical transducers 20 as shown in FIGs. 2 and 5, and indicated by dotted line 28. This orientation guarantees the greatest amount of interaction because there is interaction along the entire path of the ultrasonic compression waves.

15 It should be remembered that the ultrasonic transducers 20 are generally not subject to many of the limitations and drawbacks of all physical radiating elements described in this specification. Because the ultrasonic acoustical transducers 20 are  
20 only required to operate at extremely high frequencies, the distortion, harmonics and other undesirable features of a direct radiating element are inherently not as prevalent.

On the other hand, the present invention can  
25 generate the entire range of audible sounds, yet the ultrasonic transducer need only shift in frequency a small percentage (i.e. a 180 to 20,000 cycle shift produces the entire audio spectrum). Although this favorable character has been known, however, it has  
30 not been possible to take advantage of the improved characteristics of an ultrasonic radiating element simply because these frequencies have generally had no impact on audible sound reproduction. This invention thus makes it possible for sound reproduction to  
35 benefit from these relatively distortion free ultrasonic transducers in the sonic and subsonic spectrum.

Another aspect of the invention is the generation of unified audio frequency range signals. This is a signal which contains frequencies over the low, intermediate and high audio frequencies. Typically, this type of signal represents frequencies which are those common for voice communication and musical tone reproduction which are typically broadcast by loudspeaker systems. This is accomplished by superimposing or mixing the audio frequency range signals with one of the ultrasonic compression waves. If the respective ultrasonic compression waves have the same frequency, and one compression wave also has the audio signal mixed with it, the audible compression wave generated after interaction of the carrier waves is just the unified audio range frequency signal.

An aspect of the method above which is probably not immediately apparent is the implicit elimination of a component of most loudspeaker systems today. That component is the cross-over network which separates a unified audio frequency range signal into the low, intermediate and high audio frequency ranges. These different frequency ranges are sent to a speaker radiating element which will most efficiently transduce the corresponding electrical signals into acoustical energy. The present invention eliminates the need for a phase-distorting cross-over network. Advantageously, the present invention will generate all of the audible frequencies from approximately a near point-source at the intersection of the two ultrasonic compression waves. Consequently, the distortion caused by cross-over networks is also eliminated, along with the associated circuitry, thus saving space, cost and materials.

An additional aspect of the invention is the ability to generate sound within a broadly resonant cavity 80 as shown in FIG. 10. A resonant cavity 80

is any cavity 80 which enables compression waves to interact within a chamber which amplifies and resonates. This means that at least two ultrasonic compression waves 82 can be emitted into the cavity 80 from any perspective. In FIG. 10, two ultrasonic transducers 20 are emitting signals 82 into the cavity 80. The compression waves 82 will be reflected off the walls and interact because of the dimensions of the cavity 80. It should also be realized that a single ultrasonic emitter can be used to generate the desired compression wave, where the broadly resonant cavity 80 acts to enhance or amplify the effect.

As mentioned above, this aspect of reflection tends to emphasize or amplify the audio signal, giving a sense of source location to the sound. This feature may be applied to develop a moving point sound source which can be controlled for audio effect. For example, a train sound can literally be caused to move through a theater by projecting or reflecting the ultrasonic beam from a wall or moving object. Other techniques of controlling location of the point source of sound are envisioned, such as controlled intersection of beams.

Another example of a resonant cavity being described is the human ear canal. Not only is the human ear extremely sensitive, but the ear canal itself can function as an environment forcing interaction of the compression waves as required by the present invention. These observations provide an ideal application of the present invention and are shown generally in FIG. 11 as an ear piece 84 for hearing aids or headphones 86 for speech or music listening. The small size of the ultrasonic transducer enables the direct insertion at the ear canal, and the resonant cavity 80 provides an ideal environment for reproduction of the original sound without a physical direct radiating element. Instead,



one or two ultrasonic transducers 20 can be disposed near each ear and oriented to emit compression waves into the ear canal. This means that the ultrasonic compression waves do not need to intersect before  
5 reflecting off the interior walls of the cavity 80.

In addition to the headphone 86 and hearing aid 84 application described above, a related application of the invention involves the emission of a signal which is audible only in the intended listener's ear  
10 from a distance. By targeting the desired listener's ear a selective audience can be designated without others being able to hear the transmission. Under prior art techniques, this discreet type of audible transmission required a receiver and speaker assembly  
15 to be disposed on the person receiving the signal. Such a system was difficult to conceal. However, precise reception of two ultrasonic carrier waves at the ear of an intended recipient eliminates the need to carry a receiver and speaker assembly.

20 Another aspect of the invention relates to noise pollution. Our society has coined the phrase "boombox" to refer to portable stereo systems which have relatively large bass speakers. The boombox derives its name from the annoying side affect of a booming  
25 and repeated "thump" of the bass speakers driving large volumes of air. However, the term is also sometimes used to refer to a car or other vehicle with even larger bass speakers. Because the speakers are integrally attached to an enclosure, the vehicle or  
30 its frame, the car itself becomes a radiating element. The nature of the low frequency range also means that the it is the most amplified of all the frequency ranges by the vehicle. Consequently, persons outside the vehicle will be hit with wave upon wave of dull  
35 thumping sounds, a nuisance at best.

The present invention can thus advantageously eliminate the coupling of the vehicle to the radiating

element by generating sound in midair within the vehicle. The listener inside a vehicle can still enjoy the experience of loud bass frequencies; however, the frequencies will not be directly coupled to the enclosure because the radiating element is now a point in air. This means that the undesirable broadcasting effect into the environment beyond the immediate vicinity of the listener is significantly reduced.

10        It is to be understood that the above-described embodiments are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention. 15        The appended claims are intended to cover such modifications and arrangements.

CLAIMS

1. A method for generating at least one new sonic or subsonic wave train from at least two ultrasonic wave trains having frequencies of different value, the method comprising the steps of:

- 1) emitting from an ultrasonic radiator a first ultrasonic wave train including a base frequency into a region of a compressible transmission medium of air;
- 2) concurrently emitting from the same ultrasonic radiator a second ultrasonic wave train into the region in coaxial relationship with the first ultrasonic wave train, wherein the second ultrasonic wave train has a base frequency equal to the base frequency of the first ultrasonic wave train;
- 3) developing a beat frequency response between the first and second wave trains by varying the base frequency of the second ultrasonic wave train through a frequency range corresponding to a sum of the base frequency and the new audible sound wave train; and
- 4) emitting from the region the new audible wave train resulting from the interaction of the first and the second ultrasonic wave trains as a beat frequency output.

25

2. The method as defined in claim 1 wherein the step of generating the new audible wave train comprises the more specific step of combining the first ultrasonic frequency from the second ultrasonic frequency to yield a difference which corresponds to the new audible sound wave train and a sum which equals the sum of the first and second ultrasonic frequencies.

30

3. The method as defined in claim 1 wherein the method further comprises the step of varying the second ultrasonic frequency with respect to the first ultrasonic frequency such that the difference between

35

the varying second ultrasonic frequency and the first ultrasonic frequency is a new varying sonic or subsonic frequency which corresponds to music, speech or other audible frequencies.

5

4. The method as defined in claim 1 wherein the method comprises the more specific step of emitting the new audible wave train from the region of the transmission medium and thereby generating the audible  
10 wave train in a region of space beyond a radiating ultrasonic speaker element which can only emit ultrasonic frequencies.

5. The method as defined in claim 1 wherein the  
15 method comprises the additional step of generating both the (i) first ultrasonic frequency and (ii) the second ultrasonic frequency from a single ultrasonic signal source means, thereby eliminating frequency drift between the first and the second ultrasonic  
20 frequencies.

6. The method as defined in claim 5 wherein the method comprises the more specific step of providing at least two ultrasonic emitters which are coupled to  
25 the ultrasonic signal source means and operating the at least two ultrasonic emitters concurrently to indirectly generate the at least one new sonic or subsonic wave train, transmitting the varying signal with the ultrasonic frequency to one of the ultrasonic  
30 emitters.

7. The method as defined in claim 1 wherein the step of providing at least two ultrasonic emitters comprises the more specific step of orienting two  
35 directable ultrasonic transducers to face each other so as to be generally coaxial with respect to a transmitting surface of each emitter to thereby

maximize interaction between the first and the second ultrasonic wave trains.

8. The method as defined in claim 1 wherein the step  
5 of providing at least two ultrasonic emitters  
comprises the more specific step of orienting two  
directable ultrasonic transducers so as to transmit  
the first and the second ultrasonic wave trains  
slightly convergent, to thereby cause interaction  
10 between the first and the second ultrasonic wave  
trains.

9. A method for indirectly generating at least one  
new sonic or subsonic frequency from at least two  
15 ultrasonic wave trains of different value, the method  
comprising the steps of:

1) generating a first and a second ultrasonic  
wave train, wherein a difference in value between the  
first and the second ultrasonic frequencies of the  
20 ultrasonic wave trains is the at least one new sonic  
or subsonic frequency;

2) emitting the first ultrasonic wave train;  
3) emitting the second ultrasonic wave train in  
superimposed relationship with the first ultrasonic  
25 wave train in a region of a compressible transmission  
medium; and

4) emitting from the region the at least one new  
sonic or subsonic frequency resulting from a beat  
frequency interaction of the first and the second  
30 ultrasonic wave trains.

10. A method for indirectly generating sonic or  
subsonic compression waves in air without use of a  
direct radiating compression element, the method  
35 comprising the steps of:

1) emitting a first ultrasonic signal into an  
atmospheric region;

2) coaxially emitting from a common source a second ultrasonic signal into the atmospheric region with the first ultrasonic signal, wherein the second ultrasonic signal has a frequency which differs from the first ultrasonic signal by a frequency in the sonic or subsonic frequency range;

3) causing the first and the second ultrasonic signals to interact within the atmospheric region to develop a beat frequency response therebetween; and

4) emitting the beat frequency response as sonic or subsonic compression waves from within the atmospheric region without use of the direct radiating compression element.

11. The method as defined in claim 10 wherein the method comprises the additional step of generating the sonic or subsonic compression waves generally omnidirectional outward from within the atmospheric region, thereby approximating a near point-source of the sonic or subsonic compression waves.

12. A method for generating at least one sonic or subsonic frequency having an origin at approximately a near point-source but in the absence of a direct radiating element to thereby avoid distortion otherwise introduced by the direct radiating element, the method comprising the steps of:

1) generating a first ultrasonic frequency and a second ultrasonic frequency, the first and second frequencies having a difference equal to the at least one sonic or subsonic frequency;

2) emitting the first ultrasonic frequency as a wave train into a compressible region of atmosphere;

3) concurrently emitting from a common source the second ultrasonic frequency as a superimposed wave

train into the compressible region of atmosphere over the first ultrasonic wave train to thereby interfere with the first ultrasonic wave train; and

- 4) generating the at least one sonic or subsonic  
5 frequency so as to be emitted generally outward from the compressible region of atmosphere.

13. A method for generating music or speech having a unified audio frequency range over a range of low,  
10 intermediate and high audio frequencies, the method comprising the steps of:

- 1) directing a first ultrasonic wave train into a region of a compressible transmission medium;  
2) coaxially superimposing over the first  
15 ultrasonic wave train a second ultrasonic wave train from a common source which includes frequencies corresponding to the music or speech that differ from the first ultrasonic wave train by values within the low, the intermediate and the high audio frequency  
20 range; and  
3) concurrently generating and emitting a beat frequency output as the unified audio frequency range within the region.

25 14. A method for indirectly generating at least one audio frequency in air which is free of distortion caused by overshooting or undershooting audio range frequencies by a conventional loudspeaker diaphragm, the method comprising the steps of:

- 30 1) emitting a first ultrasonic wave train into an atmospheric region;  
2) emitting into the atmospheric region a second ultrasonic wave train which is a combination of the first ultrasonic wave train and the at least one audio  
35 frequency; and  
3) superimposing the first and second ultrasonic wave trains to concurrently generate and emit the at

least one audio frequency, without distortion, from the atmospheric region.

15. A method for indirectly generating at least one audible frequency from within a resonant cavity using at least two ultrasonic wave trains of different value, the method comprising the steps of:

- 1) transmitting a first ultrasonic wave train into the resonant cavity;
- 2) transmitting a second ultrasonic wave train into the resonant cavity, wherein the second ultrasonic wave train has a frequency value which differs from the first ultrasonic wave train by a value generally equal to the at least one audible frequency, and wherein the resonant cavity amplifies the interference between the first and the second ultrasonic wave trains;
- 3) intersecting the first and the second ultrasonic wave trains within the resonant cavity to thereby cause interference to occur between the first and the second ultrasonic wave trains; and
- 4) generating and emitting the at least one audible frequency from the interference of the first and the second ultrasonic wave trains within the resonant cavity.

16. A method for generating a unified audio frequency range wave train without using a direct radiating element which is typically coupled to an associated enclosure, thereby circumventing unintended use of the associated local enclosure as an additional radiating element, the method comprising the steps of:

- 1) emitting a first ultrasonic wave train into an atmospheric region from an ultrasonic transducer which is coupled to the associated enclosure;
- 2) concurrently and coaxially emitting into the atmospheric region from the ultrasonic transducer a



second ultrasonic wave train, wherein the second ultrasonic wave train includes harmonics having frequency values within the unified audio frequency range; and

- 5           3) emitting the unified audio frequency range wave train from within the atmospheric region and not from the first or the second ultrasonic frequency transducers, or the associated enclosure to which said transducers are coupled.

10

17. The method as defined in claim 16 wherein the method includes the more specific step of coupling the first and the second ultrasonic transducers to a vehicle which functions as the associated enclosure,  
15       thereby eliminating the vehicle as a radiating element.

18. A method for generating at least one frequency in the sonic or subsonic range wherein characteristics of  
20       the at least one frequency are not a function of physical dimensions of a radiating element, the method comprising the steps of:

- 1) emitting a first ultrasonic wave train into an atmospheric region using a first direct radiating  
25       element having defined physical characteristics;

- 2) simultaneously emitting and superimposing over the first ultrasonic wave train a second ultrasonic wave train into the atmospheric region using a second direct radiating element having defined physical  
30       characteristics, wherein the second ultrasonic wave train differs in frequency from the first ultrasonic wave train by the at least one frequency in the sonic or subsonic range, and wherein the first and the second ultrasonic wave trains acoustically interact  
35       within the atmospheric region; and

- 3) emitting the at least one sonic or subsonic frequency from within the atmospheric region

regardless of the defined physical characteristics of the first or the second direct radiating elements.

19. The method as defined in claim 18 wherein the  
5 method comprises the more specific step of using an ultrasonic transducer as the radiating element.

20. A method for controlling volume of at least one  
sonic or  
10 subsonic frequency generated in a compressible transmission medium by altering the degree of interaction of two ultrasonic wave trains, the method comprising the steps of:

1) emitting a first ultrasonic wave train into a  
15 region of atmosphere;

2) simultaneously emitting a second ultrasonic wave train into the region of atmosphere, wherein a difference in frequency between the first and the second ultrasonic wave trains is the at least one  
20 sonic or subsonic frequency;

3) varying orientation of the first and the second ultrasonic wave trains to thereby vary degree of superposition between said wave trains and consequently control volume by raising volume if the  
25 interaction is increased or lowering volume if the interaction is decreased.

21. A method for indirectly generating at least one new sonic or  
30 subsonic wave train as a by-product of emitting an ultrasonic wave train from an ultrasonic emitter, the method comprising the steps of:

1) amplitude modulating at least one new sonic or subsonic frequency onto an ultrasonic frequency to  
35 create a combination of frequencies comprising a base frequency with sideband ultrasonic frequencies;

2) emitting the combination of frequencies into a region of atmosphere from an ultrasonic emitter as a superimposed ultrasonic wave train; and

3) emitting from the region the at least one new  
5 sonic or subsonic wave train as a beat frequency output.

1/8

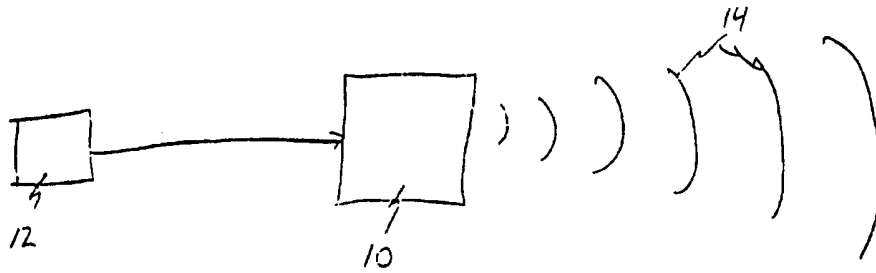


FIG. 1

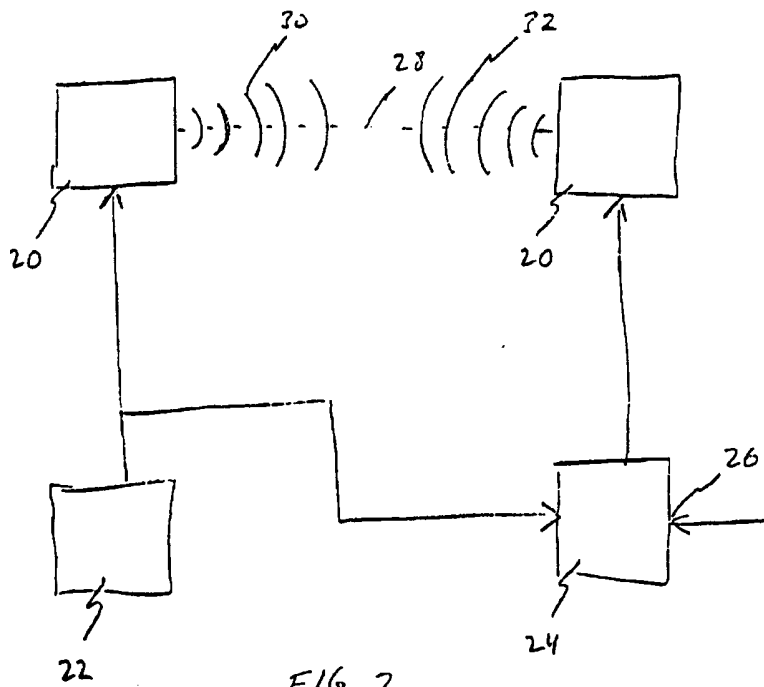


FIG. 2

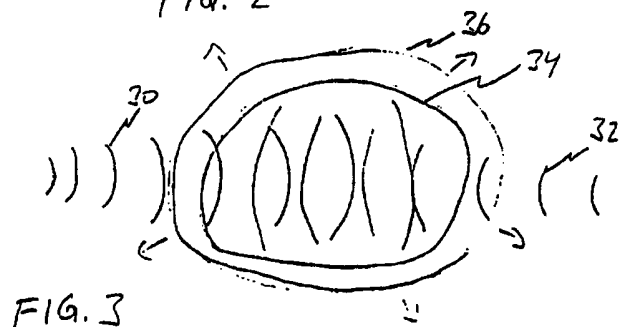


FIG. 3

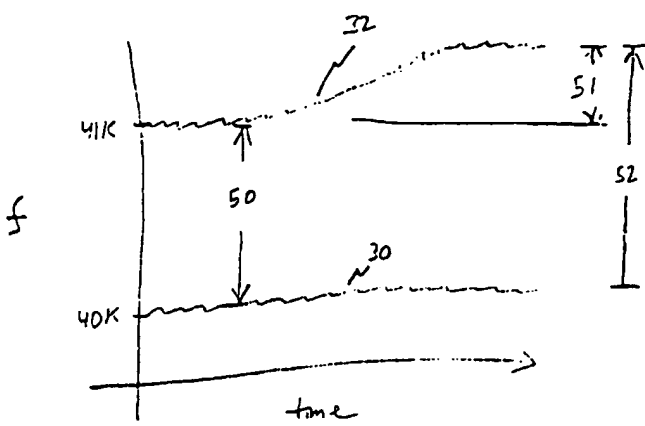


FIG. 4A

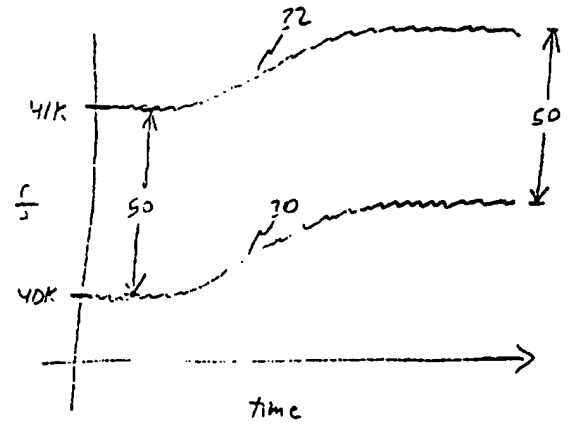


FIG. 4B

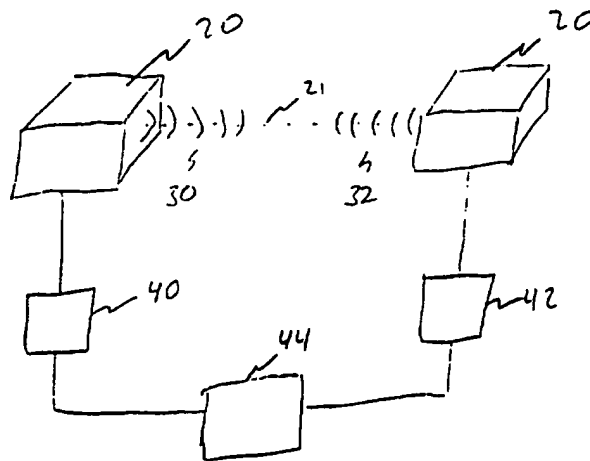


FIG. 5

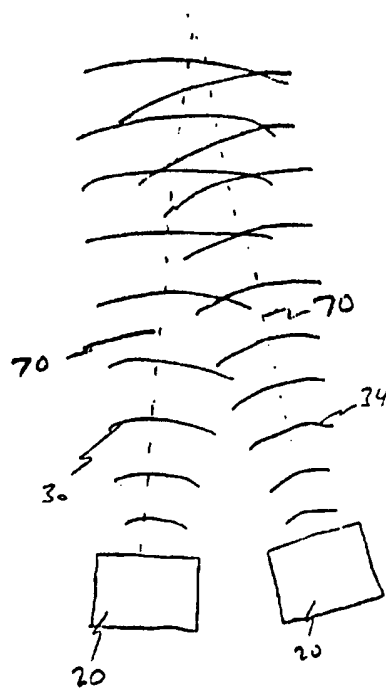


FIG. 6

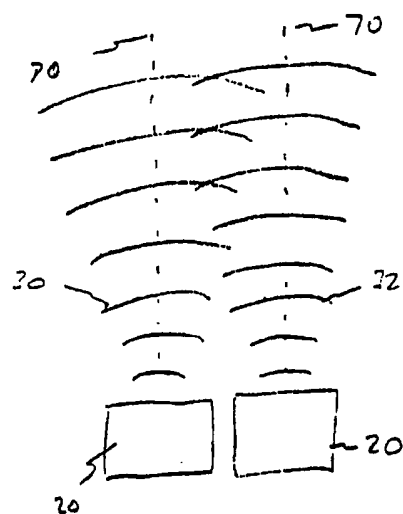


FIG. 7

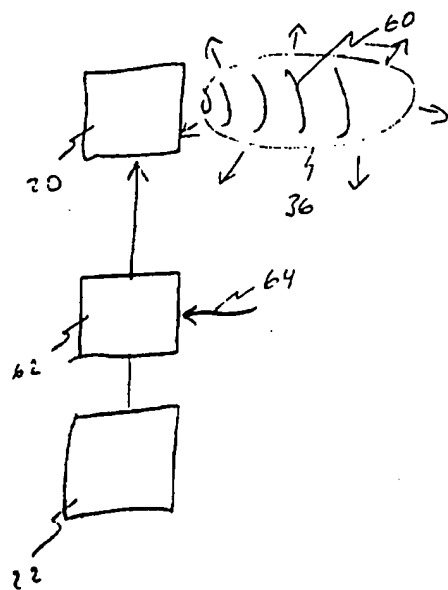


FIG. 8

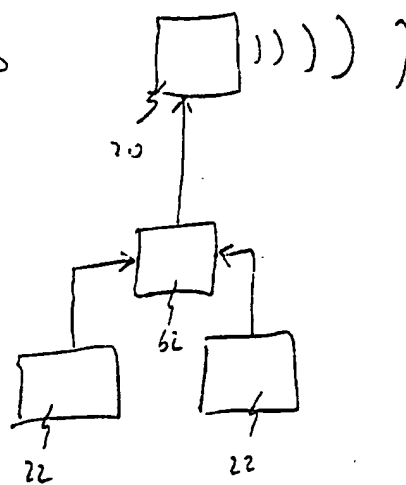


FIG. 9

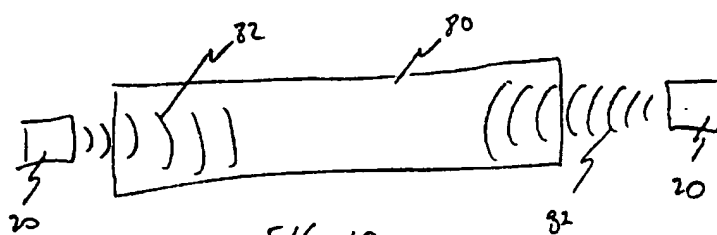


FIG. 10

5/8

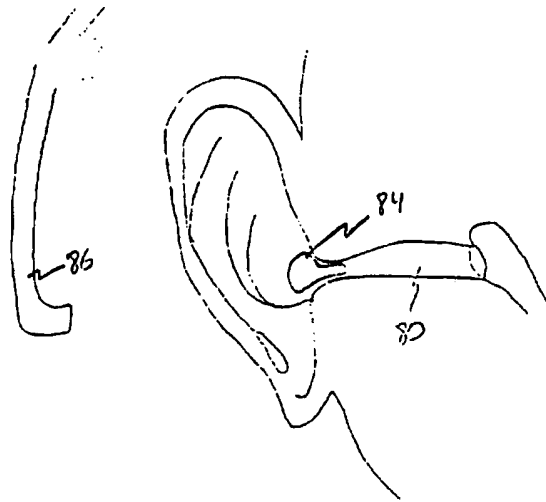


FIG. 11

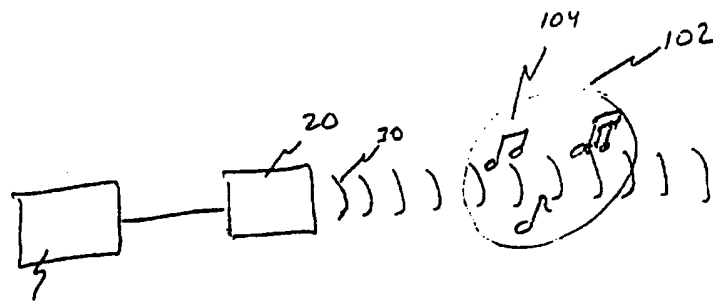


FIG. 12



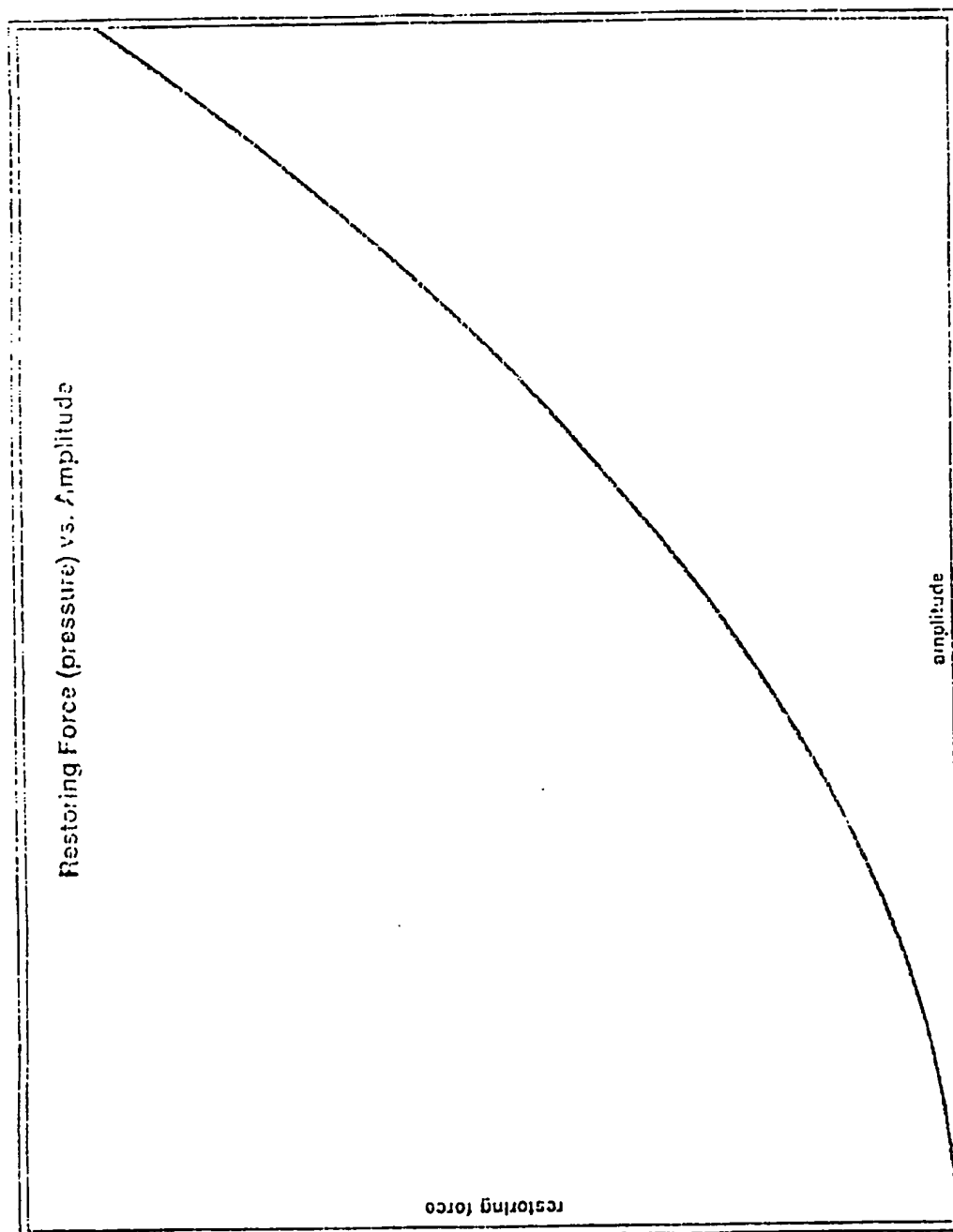


Fig. 12

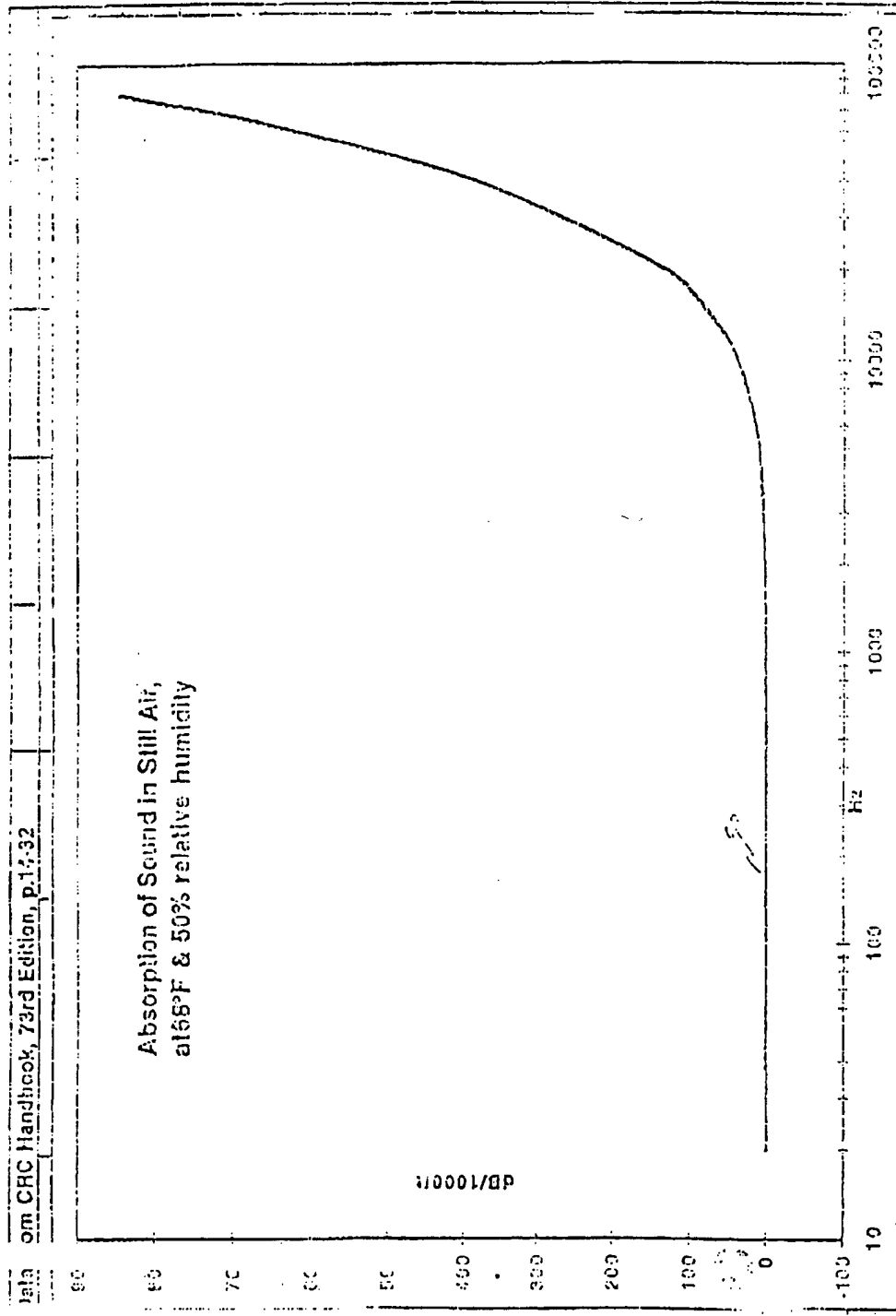


FIG. 13

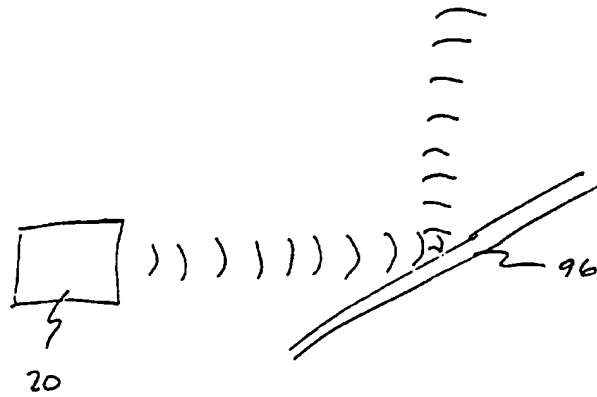


FIG. 14

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/12393

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 3/00

US CL :381/77

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/77, 79; 455/41

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 1,616,639 A (SPRAGUE) 08 FEBRUARY 1927, FIGS 1-3.	1-21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search

04 SEPTEMBER 1997

Date of mailing of the international search report

21 OCT 1997

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